# Building a VHF High Band Quad Antenna

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Much of the excitement and intrigue of scanning can be found in the 108–174 MHz VHF high band. Scanner enthusiasts can improve their reception of weak and distant signals in any segment of this band by using a high-gain antenna. Several types of commercial antennas are available, but most of those with any appreciable gain are priced over $80. However, a high-gain antenna can be built for a fraction of the cost of a commercial unit. Of the various types of high-gain antennas, one of the easiest to design and build is the quad.

## Quad Design

The typical quad antenna consists of three to five elements, an equal number of spreaders, and a boom (Figure 1). The elements are made of wire or metal rod bent into squares. The heart of the antenna is the driven element which has a permimeter 2.5% greater than that of the driven element. In front of the driven element are one or more directors which have a perimeter 3% less than the driven element's. The reflector and driven elements have their ends soldered or crimped to form unbroken squares. Where the two ends of the driven element meet, connector or terminal screws are mounted for connecting the coax from the receiver. The antenna elements are mounted on spreaders which are in turn mounted on a boom. The spreaders and boom hold the elements in the correct position with respect to one another. Both the spreaders and boom are usually made of a nonconductive material such as wood.

The gain exhibited by a quad is determined by the number of elements. A two element design, with only a driven element and reflector, will have 7.3 dB of gain compared to a dipole (nondirectional) antenna. To obtain more gain, one or more directors are placed in front of the driven element. The addition of one director raises the gain to 9.3 dB. Use of a second and third director increases the gain to 10.2 dB and 11.0 dB respectively. However, as each additional element is added to the design, the increase in gain becomes smaller and smaller. In spite of this, it's sometimes worthwhile to build quad antennas with eight or more directors.

The directivity exhibited by a quad is also determined by the number of elements. As a rule, the greater the number of elements the more directional an antenna will be. In practice the directivity of quads with eight or more elements isn't a

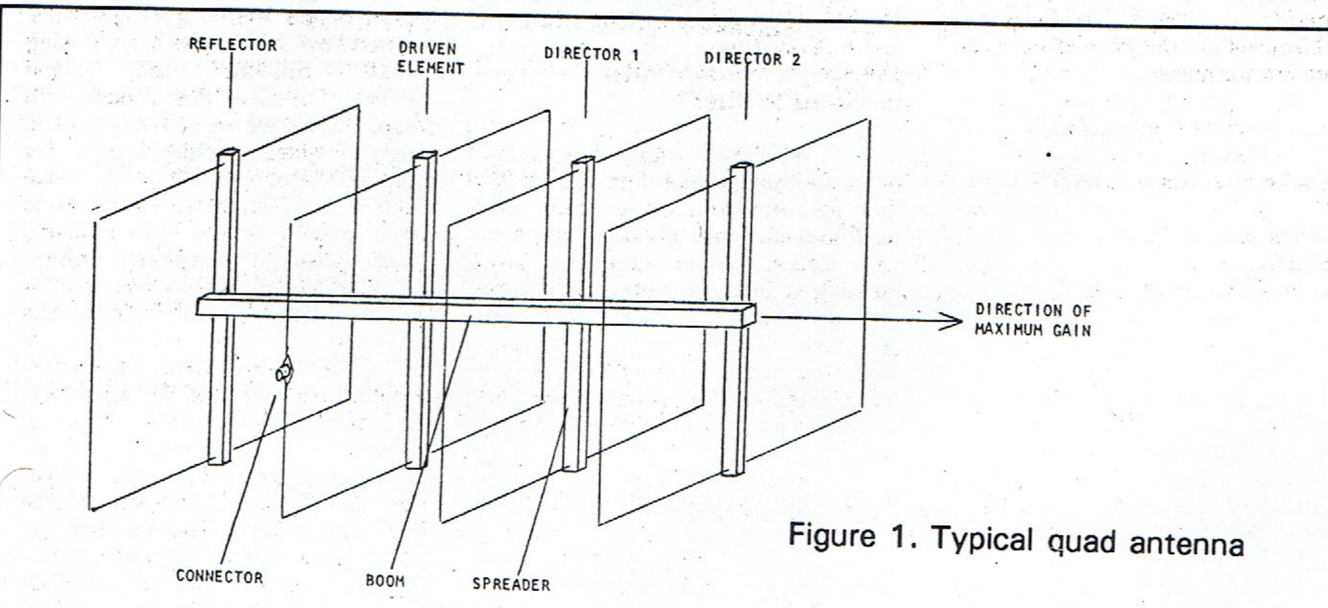



Figure 1. Typical quad antenna

Table 1. Quad antenna design data for selected frequencies

| Frequency (MHz) | Reflector Length (mm) | Driven Element Length (mm) | Director Length (mm) | Reflector-to-Driven Element Spacing (mm) | Driven Element -to-Director Spacing (mm) | Director-to-Director Spacing (mm) |
|---|---|---|---|---|---|---|
| 121.200 | 2590.3 | 2527.4 | 2452.0 | 550.4 | 403.7 | 403.7 |
| 141.000 | 2226.6 | 2172.5 | 2107.7 | 473.1 | 347.0 | 347.0 |
| 154.950 | 2026.1 | 1976.9 | 1917.9 | 430.5 | 315.8 | 315.8 |
| 156.850 | 2001.6 | 1953.0 | 1894.7 | 425.3 | 311.9 | 311.9 |
| 168.000 | 1868.7 | 1823.4 | 1768.9 | 397.1 | 291.2 | 291.2 |

handicap and is offset by the increased gain.

Although quad antennas provide gain, they only do so over a limited range of frequencies. This is referred to as bandwidth and is determined by the thickness of the elements. As a rule, the thicker the elements, the wider the bandwidth. Unfortunately, increased bandwidth comes at a price because there's a tradeoff between bandwidth and gain. Thin elements yield a bandwidth of about 3.5% while thick elements give a bandwidth of at least 8%. Therefore, a quad designed for 150.000 MHz with thin elements would provide gain over 6.0 MHz range centered on the design frequency.

The design of quad antennas is straightforward, requiring only that the lengths of the elements and their spacing be calculated. The lengths of the elements are determined using the following formulas:

Driven Element Length (feet)=
1005 divided by
Operating Frequency (MHz)

Reflector Length (feet)=
1030 divided by
Operating Frequency (MHz)

Director Length (feet)=
975 divided by
Operating Frequency (MHz)

When calculating the lengths of quad antenna elements, the thickness of the elements should be taken into account. The lengths derived from the above equations are valid for the design of VHF high bands quads if the wire or rod used for the elements has a diameter of $^1/_8$-inch or less. For elements with a diameter of ¼-inch the lengths need to be increased by 2% (use the above equations and multiply the results by 1.02).

Besides the lengths of the elements another design consideration is their spacing. The spacing of the elements is determined using the following formulas:

Driven Element-to-Reflector
Spacing (feet)= 983.6 divided by
Operating Frequency (MHz)
multiplied by 0.2225

Driven Element-to-Director
Spacing (feet)= 983.6 divided by
Operating Frequency (MHz)
multiplied by 0.1632

Director-to-Director Spacing (feet)=
983.6 divided by
Operating Frequency (MHz)
multiplied by 0.1632

Working with dimensions expressed in decimal feet (i.e. 6.28 feet) is awkward because rulers and tape measures are divided into feet and inches. When designing and building a quad, a higher degree of precision and greater ease of construction can be had by converting the dimensions from feet to millimeters. The conversion is accomplished with the formula below:

feet multiplied by 304.8= millimeters

The final quad design consideration is polarization. For any antenna to work properly it should be oriented in the same plane as the transmitting station's antenna. A quad's polarization is dictated by the orientation of the driven element side connected to the coax. If it runs up and down, as in Figure 1, the polarization is vertical; if it runs parallel to the horizon, the polarization is horizontal. Since virtually all 108–174 MHz stations use vertical polarization, the mounting hole(s) will need to be drilled into the boom so that the quad is vertically polarized.

The preceeding paragraphs contain all of the information needed to design a VHF high band quad. To simplify matters, the antenna design data for five selected frequencies is presented in Table 1. The first set of dimensions, for 121.200 MHz, are for building a quad to monitor the bottom of the VHF aero band which is used by helicopters, fixed-wing aircraft, balloons, and ground stations. The next line contains the design data for a 141.000 MHz antenna which would allow for reception of most of the 138.075–143.875 MHz federal band which is used by the U.S. military, Coast Guard Auxiliary and FEMA. The third set of dimensions are for 154.950 MHz. A quad built for this frequency would cover the 152.205–157.6948 MHz range which includes channels used by businesses, taxi companies, tow trucks, highway maintenance personnel, fire departments, local and state police. Also included in this range is the VHF marine band. The next line has design data for a 156.850 MHz antenna which would provide

reception of the 154.1052–159.5948 MHz range but is optimized for the VHF marine band. The last set of dimensions for 168.000 MHz is for constructing a quad to cover most of the 162.0125–173.9875 MHz federal band. This part of the spectrum is used by the U.S. military, ATF, FBI, IRS, Secret Service, and other federal agencies.

The data in Table 1 is also useful if you're designing a quad for a frequency not listed in the table. You can confirm that you're correctly working the design formulas by using one of the frequencies in Table 1 and comparing your results with mine. If the numbers match, you're working the equations correctly.

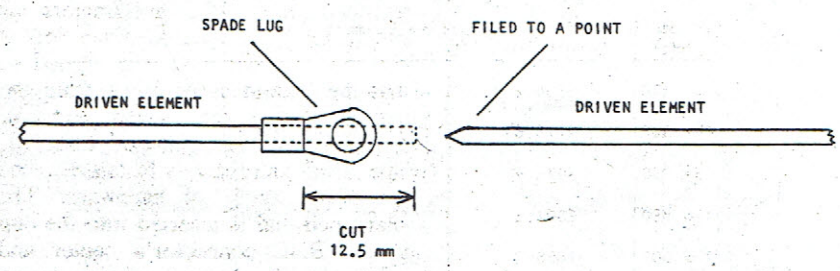
It's a good idea to fully document your final quad design. This involves writing down all of the design formulas and parameters used, the results of your calculations, and any other information describing how you arrived at your final design. Next, a detailed drawing of the antenna is made which contains all of the element dimension, spacing, and other relevant information. Use the documentation to determine the total lengths element material and spreader and boom wood required. Then file the information away in a safe place for future reference.

## The Materials

The elements can be made from any solderable solid wire or medal rod. Insulated, solid copper wire can be used as long as the insulation, which can detune the quad, is removed before use. The preferred element materal is a stiff brass or copper rod because the use of a ridgid materal will help the side of the driven element connected to the coax resist sagging under the cable's weight. Furthermore, the elements retain their shapes better when made of a ridgid material.

The spreaders and boom are both made of wood. The type of wood isn't very important and inexpensive varities such as pine or fir should suffice. When selecting wood, make sure that it's dried; straight; and free from knots, cracks, and other defects. For the spreaders, look for a length of wood that's at least $^3/_4$ x $^3/_4$-inch thick. The boom, since it supports the weight of the antenna, needs to be thicker. For a 108–174 MHz quad with three to five elements, use a length of lumber at 1 x 1-inch thick. Use a boom thickness of $1^1/_2$ x $1^1/_2$-inch for designs with six to twelve elements.

Figure 2. Preparation of driven element ends




The other items needed to build a quad are a flange-type female BNC connector; #8 bolts, nuts, and washers; a #4 screw, nut and washers; Kester 2% silver/98% tin solder (part number 82505) or equivalent low temperature silver solder; Plumber's Goop or similar adhesive/sealant; butt connectors; and electrical tape. While almost any flange-type female BNC connector can be used, I recommend military specification connectors. Mil-spec connectors have a center insulation made of Teflon which withstands the heat of soldering. Likewise, although any electrical grade lead/tin solder can be used to build the antenna, I advise using silver-bearing because it's much stronger. The Achilles' heel of the quad is where one of the ends of the driven element is soldered to the center of the BNC connector. This solder joint, if made of lead/tin solder, can be easily broken by repeated flexing. Silver solder, however, creates a much stronger connection that's much more flex resistant.

## Construction

If you're making the elements from insulated wire, tie one end of the wire to a fence post or other anchor, pull on the wire, and carefully strip the insulation with a single edged razor blade or knife. Then grab the far end of the wire and pull hard in order to straighten it.

Next, the elements are made one at a time. Use a ruler with a millimeter scale to measure off the total length of material needed for the element and then mark it. The

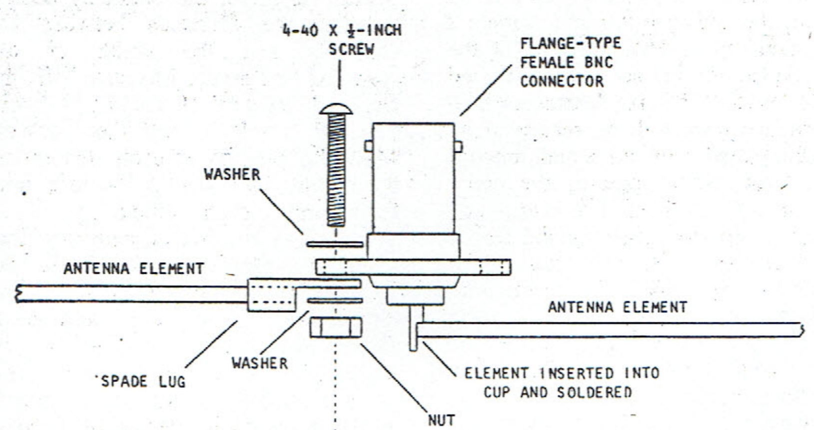
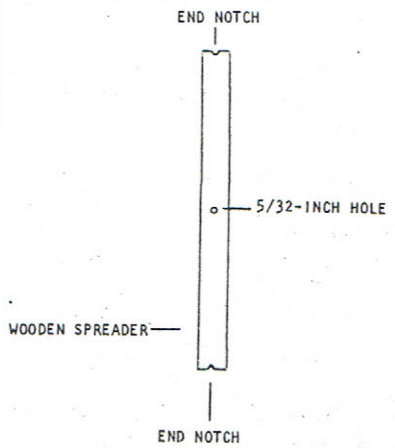



Figure 3.
Connection of driven element to BNC connector

Figure 4.
Finished spreader




material is then cut or sawed. Using the ruler, mark the places on the element where the bends will be made, but make sure that the marks are correctly placed so that the ends will meet halfway on one of the sides.

The element is then bent into a square. Metal rod can be difficult to bend due to its stiffness. Bends with uniform curves can be obtained by doing the following: Place the jaws of a pair of pliers 5 millimeters to one side of a bend mark and bend the material a few degrees. Then place the pliers an equal distance on the other side of the mark and bend the material on equal amount. Continue the process of placing the pliers on each side of the mark and slightly bending the material until you have a 90° bend.

Once the reflector and each director has been formed into a square, the ends are joined to create a continuous loop. Examine one of the butt connectors and see if it's crimped in the middle. If it is, determine how far the two ends will be separated by the crimp and trim an equal amount of material off of one of the ends. This is done to keep the crimp and resulting gap from altering the length of the element. The two ends of the element are pushed into the butt connector, the connector crimped over the ends, and the connector and ends soldered together. When each element is finished, label it (reflector, director, ect.) so that you can later tell the elements apart.

After the driven element has been bent into a square, the ends are prepared and the element and BNC connector are joined. One of the ends is filed to a point and the other trimmed back 12.5 millimeters as shown in Figure 2. A spade lug is slid over the trimmed end, turned so that the bottom faces away from the center of the the driven element, crimped onto the end, and soldered. The BNC connector is fastened to the spade lug using #4 hardware. The sharpened end is inserted into the cup in the BNC connector's center and soldered. The joining of the driven element and the BNC connector is detailed in Figure3.

Each spreader is also made one at a time. Take the wood to be used for the spreaders and draw two lines across it that are the same distance apart as opposite sides of the element. Drill a hole in the center of the wood on each side of the lines. Saw through the wood and the centers of the holes. Then find the center of spreaders and drill a $^5/_{32}$-inch hole. The finished spreader should resemble the one in Figure 4.

Next, each element is mounted onto its spreader. Slide each element over the spreader until it fits into the end notches. Carefully center the spreader in the center of the element, apply generous amounts of Plumber's Goop to each end of the spreader, and then label the spreader with the element's name (reflector, director 1, director 2, etc.). Allow the adhesive to cure for several hours.

The boom is the final part of the quad to be made. Calculate the overall length of the boom by adding together the distances between the elements and the width of the spreader material. Measure off the required amount of length of boom material, mark it, and then saw it. Mark the position of each element on the boom. Then drill a $^5/_{32}$-inch hole for mounting each element.

The antenna is ready for final assembly. One by one, slide the reflector, driven element, and director(s) over the boom and screw them down Pick up the quad, find its center of balance, and mark it. Drill the hole(s) for mounting the antenna to the mast at the center of gravity. Be sure to orient the holes so that the quad is vertically polarized. Connect the coax to the BNC and run it away from the antenna for a distance of about 455 millimeters. Then loop it back into the quad between the driven element and director, run it along the boom out the back of the antenna, and then use electrical tape to hold the coax in position. Check the solder joint between the center of the BNC connector and the end of the driven element to verify that it's not broken. If everthing's in order, apply Plumber's Goop liberally over the entire BNC connector and the end of the coax to seal out moisture. The Quad is now complete.

## Installation

Before installing the antenna, make absolutely sure ther are no power, telephone, or cable TV lines near the point of installation. Under no circumstances attempt to erect the quad anywhere near such a cable. Not following this advise could result in death by electrocution.

If the desired location is safe, mount the antenna to the mast and raise it so that it's away from metal objects and clears any local obstruction. Aim the quad in towards the intended target area and secure it. Run the coax out of the back of the antenna and let it drop down. If you live in an area that's prone to lighting, take the required steps to make your quad and mast lighting safe.

Reception in any portion of the 108–174 MHz range can be greatly improved by use of a quad antenna. A quad with 9 dB or more of gain can be easily designed using a small number of simple formulas and a precision antenna can be fabricated from inexpensive materials using basic tools.

## References

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